

# In Time and Velocity, Which Component Would Appear Dilated to the Observer?

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## Abstract

Based upon the aberration of starlight, an attempt is made to explain the experimental facts of importance concerning the special theory of relativity. The physics behind the formalism is the center of attention in this attempt. It is demonstrated that the Galilean concepts of time and simultaneity, in contrast to the currently accepted view, are natural for describing special relativity physics.

## 1 Introduction

Einstein's special theory of relativity has become a commonplace in modern physics, as taken for granted as Newton's law of classical mechanics or the Maxwell equations of electromagnetism. However, it was resisted for many years because of the second postulate on which the theory is based. The second postulate, which states that the speed of light is independent of the motion of its source, destroys the concept of time as a universal variable independent of the spatial coordinates. Because this was a revolutionary and unpalatable idea, many attempts were made to invent theories that would explain all the observed facts without this assumption. Our changed idea about space and time is the result of its gradual establishment through experiments in violent controversy.

This work is another such attempt. In contrast to previous works, I have attempted to find a phenomenological explanation of special relativity physics. In this paper, I wish to address the physics behind the aberration effect as the origin of special relativity physics. This interpretation eliminates the second postulate; there is no need to make any postulates. It should be noted that the present interpretation is based upon the Galilean concept of time and is consistent with all the observed facts of importance concerning the special theory of relativity. This paper will show how relativistic phenomena can naturally be understood in terms of the classical concepts of time and simultaneity. However, it is not intended to be a discussion concerning the general theory of relativity.

## 2 Ether Drift

We consider the well-known experiments related to the speed of light in a moving medium [1]. The Michelson-Morley experiment was undertaken to investigate the possible existence of the ether drift. In principle, it consisted merely of observing whether there was any shift of the fringes in the Michelson interferometer when the instrument was turned through an angle of  $90^\circ$ . The negative result shows that it is impossible to demonstrate the existence of the ether drift. This was interpreted as demonstrating the absence of the ether drift. However, it could have been due to the experiment itself being incapable of demonstrating the ether drift.

Fizeau performed an important experiment to determine whether the speed of light in a material medium is affected by motion of the medium relative to the source and observer. In the Fizeau experiment, an alteration of the speed of light was observed, which was in reasonable agreement with the value given by Fresnel's dragging formula. From a comparison of the Fizeau experiment with the Michelson-Morley experiment, we realize that the arrangement of the Michelson-Morley experiment makes it impossible to detect the ether drift. In the Michelson-Morley experiment, both the source and the observer are at rest while the ether is in uniform motion through the arrangement. As viewed from the Fizeau experiment, the ether drift cannot be defined in this arrangement. The circumstances are the same as for the Earth, whose motion cannot be defined without an extraterrestrial reference. Even if the Michelson-Morley experiment is performed, for example, in water flowing rapidly in one direction, the null result is expected since the velocity of the water flow cannot be defined in this arrangement. In the case of sound under the same circumstances, as it should be, no change of pitch was observed [2].

We should mention the Michelson-Morley experiment performed with an extraterrestrial light source. Apparently, the motion of the light source relative to the half-silvered mirror is ineffective in changing the interference pattern. As shown in the Michelson interferometer, only the motion of the half-silvered mirror relative to one of the other two mirrors can give rise to an effect on the interference fringes. It is clear that the point of splitting into two beams plays the role of an effective source in that interferometer. The experiment using sunlight differs from the original only in the domain of taste rather than coverage.

## 3 Twin Paradox

Einstein showed that the Lorentz transformation which preserves the speed of light in all uniformly moving systems requires revision of the usual concepts of time and simultaneity. He was thus led to the result that a moving clock runs more slowly than a stationary clock. However, such a concept of time gives rise to the twin paradox. In mechanics, it is impossible by means of any physical measurements to label a coordinate system as intrinsically "stationary" or "uniformly moving"; one can only infer that the two systems are moving relative to each other. According to this fundamental postulate, like velocity and distance, time must also be symmetric with respect to the two systems. This is what the twin paradox points out.

We consider the experiments performed to verify the phenomenon of time dilation. The mean lifetime of  $\pi$ -mesons was determined using the decay of  $\pi$ -mesons at rest in a scintillator [3]. In this method, the mean lifetime of the  $\pi$ -mesons

was determined by a direct measurement of the time required to decay. In order to investigate the phenomenon of time dilation, an attempt to measure the mean lifetime of a rapidly moving  $\pi$ -meson beam was undertaken [4]. An experiment of this nature was arranged to measure the attenuation in flight of a  $\pi$ -meson beam of known lifetime using a scintillation counter telescope of a variable length. The measured mean free path was divided by the mean velocity to get the mean lifetime. The mean lifetime thus obtained, when the Lorentz time dilation was taken into account, was in fair agreement with the data measured in the rest system of  $\pi$ -mesons. It is generally recognized that these experiments have verified the phenomenon of time dilation.

However, the latter experiment has an ambiguous bearing on the phenomenon of time dilation. In that experiment, the relativistic correction was made directly in the mean lifetime, keeping the particle velocity intact. This is otherwise without example in high-energy physics experiments, where the relativistic correction has been made in the form of four-vector velocity.

The space component of the velocity four-vector is defined as the rate of change of the path of a particle with respect to its proper time. Based upon this definition, one may say that the four-velocity results from the Lorentz time dilation, and thus they are compatible. However, the current definition disregarding the dilation of its proper path is not based upon experimental fact. Observation of the dilated mean free path of  $\pi$ -meson beam with respect to its proper lifetime points out that once the Lorentz time dilation is taken into account, there is no room for the four-velocity formulation. Either the time dilation or the four-velocity, not both of them, can be consistent with experimental observation. This means that the time dilation and the four-velocity are alternatives, so that the four-velocity cannot result from the Lorentz time dilation. The question naturally arises, "In time and velocity, phenomenologically, which component would appear dilated to the observer?" To see the truth, the mean lifetime of a rapidly moving  $\pi$ -meson beam must be determined by direct measurement. The mean lifetime so determined will be the same as the data measured in the rest system of  $\pi$ -mesons if what the twin paradox points out is correct. Although such an experiment was probably undertaken, there does not seem to be a publication that describes the experiment of this kind. In spite of this, we can infer the result from a comparison with astronomical observation.

In 1971, Shapiro observed that the components making up the nucleus of radio source 3C279 were in motion [5]. Surprisingly, the speed of the components was estimated to be about ten times the speed of light! The activity, which occurs on a scale of milliseconds of arc, could not have been detected with the techniques available before the early 1970s. Special attention was immediately given to observation of the mysterious phenomenon, from which some other quasars such as 3C273 also turned out to be superluminal sources. From direct observations of the distances traveled and the times required, it is reported that their nuclei contain components apparently flying apart at speeds exceeding the speed of light. The concept of the speed of light as a limiting speed of material particles, which has been confirmed in physics, has been questioned in astronomy.

It seems that the  $\pi$ -meson experiment and the observation of superluminal motion are physically equivalent. The only difference would be in their explanations. On the comparison of the experiment with the observation, we come to see that,

phenomenologically, the velocity component itself would appear dilated to the observer, keeping the time intact. It is certain therefore without requiring explicit experiment that the mean lifetime of a rapidly moving  $\pi$ -meson beam obtained by direct measurement is equivalent to the mean lifetime in the  $\pi$ -rest system. This constitutes a verification of the prediction of equal ageing of the twins in relative motion. It confirms fully that the phenomenon of time dilation is a result of confusion. As has been pointed out by the twin paradox, the current concepts of time and simultaneity violate the relativity of uniformly moving systems.

## 4 Aberration of Starlight

The Bradley observation of the aberration of starlight seems to be even more important to modern physics than previously thought. This is because the aberration of starlight can be interpreted as expressing the covariant equations of motion leading to special relativity physics. The physics behind the aberration effect is discussed in this section.

In 1727, Bradley discovered an apparent motion of star which he explained as due to the motion of the Earth in its orbit. This effect, known as aberration, is quite distinct from the well-known displacements of the nearer stars known as parallax. Bradley's explanation of this effect was that the apparent direction of the light reaching the Earth from a star is altered by the motion of the Earth during propagation. The reason for this is much the same as that involved when a little girl walking in the rain must tilt her umbrella forward to keep the rain off her feet.

Let the vector  $\mathbf{v}$  represent the velocity of the Earth relative to a system of coordinates fixed in the solar system, and  $\mathbf{c}$  that of the light relative to the solar system. Then the velocity of the light relative to the Earth has the direction of  $\mathbf{c}'$ , which is the vector difference between  $\mathbf{c}$  and  $\mathbf{v}$ . This is the direction in which the telescope must be pointed to observe the star image on the axis of the instrument. When the Earth's motion is perpendicular to the direction of the star, the relation  $c'^2 - v^2 = c^2$  follows from the vector difference. If we set  $c' = kc$ , we see that the observation is performed at speed  $c'$  greater than when the Earth is at rest. Keeping in mind that the speed of light can be a measure of speed, the altered speed of observation is conjectured to give rise to the same effect as would be the case if the velocity scale were correspondingly altered at the moment of observation. Accordingly, the velocity of the Earth is supposed to be  $v' = kv$  in relation to the observation. Taking this velocity of the Earth, the Bradley relation becomes  $c'^2 - v'^2 = c^2$ . The velocity scale can then be written in the closed form  $k = 1/(1 - v^2/c^2)^{1/2}$ , which is just the  $\gamma$ -factor in relativity. The appearance of the  $\gamma$ -factor as the velocity scale has nothing to do with relativity but rather is of a purely observational nature. As a consequence of this consideration, the relations for the angle of aberration  $\alpha$  can be written as

$$\sin \alpha = \beta, \quad \cos \alpha = (1 - \beta^2)^{1/2}, \quad \tan \alpha = \beta/(1 - \beta^2)^{1/2}, \quad (1)$$

where  $\beta = v/c$ .

At this point, it is necessary to examine the difference between the present interpretation and the relativistic explanation. In the present interpretation, the velocity of the Earth and the velocity of light relative to it are respectively assumed

to be  $\gamma v$  and  $\gamma c$ , while the velocity of light relative to the solar system at rest is  $c$ . If the distance to the solar system is  $R$ , the distance to the Earth is  $\gamma R$ . Regardless of whether the Earth is in motion, therefore, the time required for light to reach the Earth is  $R/c$ . These assumptions are in contrast with those in the relativistic explanation. In the relativistic explanation, the velocity of the Earth and the velocity of light relative to it are respectively  $v$  and  $c$ , whereas the velocity of light relative to the solar system at rest is assumed to be  $c/\gamma$  in the Earth's frame [6]. So, the time required to reach the Earth is here  $\gamma R/c$ . Note that in spite of their difference, both the present interpretation and the relativistic explanation result in the same relations for the angle of aberration.

The aberration of starlight shows us an essential change in observation due to the finite velocity of observation. We are going to examine its effect on the equations of motion. From the vector difference between  $\mathbf{c}'$  and  $\mathbf{v}'$  for the velocity of light, a derivative with respect to time gives the covariant equation of accelerations

$$\frac{d\mathbf{c}'}{dt} - \frac{d\mathbf{v}'}{dt} = \frac{d\mathbf{c}}{dt} = 0. \quad (2)$$

The scalar product of the accelerations in this equation with the corresponding velocity vectors is written

$$c' \frac{dc'}{dt} - v' \frac{dv'}{dt} = 0, \quad \text{so} \quad c \frac{d(\gamma c)}{dt} - v \frac{d(\gamma v)}{dt} = 0. \quad (3)$$

Equation (3) can also be obtained by differentiating the Bradley relation  $c'^2 - v'^2 = c^2$  with respect to time. The kinetic energy  $T$  is defined in general to be such that the scalar product of the force and the velocity is the time rate of change of  $T$ . In comparing (3) with the definition of  $T$ , the relativistic expression of kinetic energy  $T = mc^2/(1-\beta^2)^{1/2}$  is seen [7]. In the present discussion, the mass has been treated as a constant [8]. The Bradley relation  $c'^2 - v'^2 = c^2$  can therefore be expressed in terms of the kinetic energy and momentum, which is seen to be the covariant energy-momentum equation with  $T^2/c^2 - p^2 = m^2 c^2$ . It shows how the relativistic equations of motion can be derived on Newtonian mechanical grounds.

Since the aberration effect is attributed to the finite velocity of observation which is affected by motion of the Earth, it is thought that relativistic phenomena would appear due to the measurement velocity being affected by velocity of a moving body, like a vector difference between velocities. This illustrates why relativistic phenomena appear more pronounced as particle velocities approach the velocity of light. The physical idea is obvious. Is the relativity effect just an effect due to the measurement velocity being affected by the velocity of a moving particle? Understood as such, special relativity physics is identified itself as denoting the branch of physics which takes into consideration even the measurement velocity as affected by the particle velocity. Then the physical meaning of why the velocity of light would appear in the equations of motion of a material particle is not at all recondite. In this regard, a particle speed as fast as or faster than light, apart from the possibility of existence, is unobservable in a direct way because such a particle goes beyond the observation speed.

We suppose that the Earth is uniformly moving with velocity  $\mathbf{v}$  with respect to the solar system. For simplicity, let the origins of the coordinates of the Earth and the solar system be coincident at time  $t = 0$ , at which time the star emits a pulse

of light. If this pulse of light reaches the solar system at a time  $t$ , the propagation paths of the light to the solar system and the Earth are respectively given by  $R = ct$  and  $R' = c't$ . Let  $x$  and  $x'$  be the respective projections of  $R$  and  $R'$  along the direction of  $\mathbf{v}$ . Then the geometric figure of the aberration of starlight gives

$$c^2t^2 - x^2 = c'^2t^2 - x'^2. \quad (4)$$

The Bradley observation of the aberration of starlight suggests taking  $c't$  as a fourth coordinate in place of  $ct'$  as used in the Lorentz condition. The fact that the geometric figure of the aberration of starlight draws the covariant equation of coordinates seems to me to form the background for the point of view that the physics of special relativity has its origin in the aberration of starlight. Physically, the solar system in the discussion of aberration should be understood as the retarded position of the Earth.

The Bradley relation in (4) stands in contrast with the Lorentz condition leading to the Lorentz transformation with respect to the concepts of time and the speed of light. The Bradley relation describes the simultaneous arrival of light signals starting from the star at the two points  $x$  and  $x'$  in relative motion. In contrast with this, the Lorentz condition finds a physical interpretation in a spreading spherical wave which starts from the star and reaches the point  $x$  at time  $t$  and the point  $x'$  at time  $t'$ . Figure 1 shows the difference between the Bradley relation and the Lorentz condition. Recalling the Doppler effect, there is no doubt that the velocity of light is not independent of the motion of its source. The invariance of the velocity of light in all uniformly moving systems, which plays so decisive a role in the Lorentz transformation, has an ambiguous bearing on the experimental facts. To be consistent with observation for the aberration of starlight, the Doppler shift, and the Michelson-Morley experiment, the second postulate should be replaced by the restricted, but more accurate, postulate that the velocity of light appears the same in all uniformly moving systems if and only if the source and the observer are both in a given system. It is then apparent that the Lorentz condition has no bearing on the two systems in relative motion. The Lorentz transformation turns out to be a result of an ill-conceived marriage.

The fourth component of the Lorentz transformation is worthy of mention. The relation of the retarded coordinates to the present coordinates of the Earth is given by the Lorentz transformation using equation (4) instead of the Lorentz condition. The fourth component of this transformation is written

$$c' = \frac{c(1 - \beta \cdot \mathbf{n})}{(1 - \beta^2)^{1/2}} \quad \text{from} \quad c't = \frac{ct - vx/c}{(1 - \beta^2)^{1/2}}, \quad (5)$$

where  $\mathbf{n}$  is a unit vector in the direction of  $\mathbf{R}$ . Since the ratio between  $x$  and  $ct$  is the direction cosine of the propagation path of light with respect to  $\mathbf{v}$ , it can be expressed in the more familiar form of the Doppler shift formula. It is of particular interest to note that the fourth component of the modified Lorentz transformation gives a more general derivation of the relativistic formula for the Doppler shift. Consequently it leads us to consider the transverse Doppler shift as due to the aberration effect, and thus as observed in the direction inclined at the angle of aberration toward the direction of motion of a moving source.

We can also give a more general derivation of the expression for the angle of aberration. The ratio between the  $x$  component and the fourth component of this

transformation can be written using the direction cosines as

$$\cos \theta' = \frac{\cos \theta - \beta}{1 - \beta \cos \theta} \quad \text{from} \quad \frac{x'}{c't} = \frac{\gamma(x - vt)}{\gamma(ct - vx/c)}. \quad (6)$$

This is the same expression as given by Einstein in his original paper. It has been shown algebraically that two successive Lorentz transformations with velocity parameters  $\beta_1$  and  $\beta_2$  are equivalent to a single Lorentz transformation of parameter  $\beta = (\beta_1 + \beta_2)/(1 + \beta_1\beta_2)$ , by multiplying the matrices of the two separate transformations. This formula for the addition of velocities also follows from the ratio in (6), in consequence of the interpretation of  $x/ct$  as the velocity parameter of a particle in its rest system and  $x'/c't$  as the velocity parameter of observer in the laboratory.

## 5 Aberration of Fields

Newton's law of universal gravitation is a classical notion in the sense that it means a complete neglect of propagation of force. If the gravitational field propagates with the velocity of light, the gravitational field must suffer aberration, just as light does. It is then found that the aberration of starlight expresses the aberration of the gravitational field of star.

Let  $\mathbf{R}$  be the radius vector from a star to the retarded position of the Earth. If the star is in a direction perpendicular to the motion of the Earth, the length of the path along which starlight propagates to the Earth is given by  $R/\cos \alpha = R/(1 - \beta^2)^{1/2}$  in the direction of  $\mathbf{n} - \beta$ , where  $\alpha$  is the angle of aberration. The gravitational field of the star can therefore be written in terms of the retarded and present times of the moving Earth as

$$\left[ \frac{GM}{R^2} \right]_{t-R/c} \quad \text{and} \quad \left[ \frac{GM(1 - \beta^2)}{R^2} \right]_t, \quad (7)$$

where  $M$  is mass of the star. Equation (7) describes the aberration of gravitational field. It shows that the gravitational field at the point of observation at time  $t$  is determined by the state of motion of the Earth at the retarded time  $t - R/c$ , for which the time of propagation of light from the star to the observation point just coincides with  $R/c$ . The alterations in the direction and magnitude of the gravitational field are attributed to the propagation velocity of the field as affected by the motion of the Earth.

We can extend this to the case where the star is not in a direction perpendicular to the motion of the Earth. The propagation path of starlight to the Earth is then given by (5) as  $R' = R(1 - \beta \cdot \mathbf{n})/(1 - \beta^2)^{1/2}$ . The aberration of gravitational field can thus be expressed in the general form

$$\frac{GM(1 - \beta^2)}{R^2(1 - \beta \cdot \mathbf{n})^2}. \quad (8)$$

If we take the path of integration to be  $R'$ , the distance from the star to the point of observation, we obtain for the gravitational potential the expression

$$\frac{GM(1 - \beta^2)^{1/2}}{R(1 - \beta \cdot \mathbf{n})}. \quad (9)$$

It is thought possible to express in a covariant form this aberration effect on the gravitational field. The gravitational field acting on the Earth is different in direction and magnitude from that when the Earth is at rest. In the geometric figure the difference is shown to be an acceleration that the moving Earth has during the propagation. The spatial variation in propagation of the gravitational field may therefore be expressed in the form

$$\left[ \frac{GM}{R^3} \mathbf{R} \right]_{t-R/c} \Rightarrow \left[ \frac{GM}{R'^3} \mathbf{R}' + \frac{d\mathbf{v}'}{dt} \right]_t. \quad (10)$$

This equation shows that the gravitational field acting on a moving system must be balanced by an acceleration the system would have during propagation. Total gravitational effects observed at a moving system will thus be the same, regardless of how fast it moves. This makes gravitational force invariant in the covariant form of equation. But the gravitational force is no longer directly related to the gravitational acceleration, the two quantities being in general in different directions.

Following the same line of reasoning, the aberration of the Coulomb field produced by a moving electron can be expressed in the form of (8) by replacing the gravitational charge  $GM$  by the electronic charge  $e$ . The electric field so obtained is similar to the Coulomb field of an electron in uniform motion in electrodynamics. We now compare the Liénard-Wiechert potential with the potential given in this approach:

$$\left[ \frac{e}{R(1 - \beta \cdot \mathbf{n})} \right]_{t-R/c}, \quad \left[ \frac{e(1 - \beta^2)^{1/2}}{R(1 - \beta \cdot \mathbf{n})} \right]_t. \quad (11)$$

Since the relation of the retarded position to the present position of a moving electron is not, in general, known, the Liénard-Wiechert potential ordinarily permits only the evaluation of the field in terms of retarded position and velocity of the electron. In the present approach, the unknown effect occurring during the propagation is assumed to be the aberration of the field attributed to its finite propagation velocity. As applied to a moving source of light, the propagation path of light to the observer yields an expression equal to the relativistic formula for the Doppler shift. This favors the assumption. The unknown effect occurring during the propagation would be the aberration of the Coulomb field produced by a moving electron.

In electrodynamics, the electric field of a moving electron divides itself into “a velocity field,” which is independent of acceleration, and “an acceleration field,” which depends linearly upon acceleration. The velocity field is essentially static field, whereas the acceleration field is typical radiation field. In the present approach, the Coulomb potential alone induces the velocity field. Thus to make this approach agree with the electric field of a moving electron, the vector potential should be deduced solely from the radiation field. On the assumption that the relativistic correction to the velocity component of vector potential involves the cancellation of the factor  $(1 - \beta^2)^{1/2}$  arising from the propagation path, this deductive reasoning leads to the following forms of expression for the vector potential:

$$\frac{e}{c} \left[ \frac{\mathbf{v}}{R(1 - \beta \cdot \mathbf{n})} \right]_{t-R/c}, \quad \frac{e}{c} \left[ \frac{\mathbf{v} - (\mathbf{v} \cdot \mathbf{n})\mathbf{n}}{R(1 - \beta \cdot \mathbf{n})} \right]_t. \quad (12)$$

This suggests that the component of the velocity perpendicular to  $\mathbf{n}$  plays the role of an effective velocity in the evaluation of the vector potential. When we view (12)

in this way, we realize that the component of the velocity parallel to  $\mathbf{n}$  has been incorporated in the propagation path. Taking into account the geometrical image of the velocity, it is reasonable to expect that the vector potential of (12) expresses an effect occurring during its propagation. In the intuitive form, actually, this vector potential describes the transverse radiation fields:

$$\mathbf{n} \cdot \mathbf{A} = 0,$$

$$\mathbf{E} = -\frac{1}{c} \frac{\partial \mathbf{A}}{\partial t} \Rightarrow -\frac{1}{c(1 - \beta \cdot \mathbf{n})} \frac{\partial \mathbf{A}}{\partial t_{ret}} = \frac{e}{c^2} \frac{\mathbf{n} \times \{(\mathbf{n} - \mathbf{v}) \times \dot{\mathbf{v}}\}}{R(1 - \beta \cdot \mathbf{n})^3}. \quad (13)$$

In the above equation we have differentiated the retarded velocity with respect to the retarded time through the relation  $dt = (1 - \beta \cdot \mathbf{n})dt_{ret}$ . The radiation field given here is in exact agreement with the familiar result, leading to the same form as the general expression for the energy detected at an observation point. The deductive scheme for the vector potential lends itself to incorporation in the classical theory of radiation.

So far the aberration of radial fields has been discussed, nothing has been said about the physical significance of the aberration of uniform fields. We consider the motion of an electron in a uniform magnetic field  $\mathbf{H}$ . If the electron has no velocity component along the field, it moves along a circle in the plane perpendicular to the field. The electron moving in the field satisfies the equation  $mv^2/r = e\mathbf{v}/c \times \mathbf{H}$ , where the electron's velocity is denoted by  $\mathbf{v}$ . There would be an aberration of uniform magnetic field because of its finite propagation velocity. The apparent direction of the uniform magnetic field will be inclined at an angle of aberration from that given at the retarded time. The physics of the situation is reminiscent of the aberration of starlight, with the field replacing starlight and the electron replacing the Earth in its orbit. The angle between  $\mathbf{v}$  and  $\mathbf{H}$  must be  $\pi/2 - \alpha$ , instead of being  $\pi/2$ , where  $\alpha$  is the angle of aberration. The equation of motion is thus written  $mv^2/r = (evH/c) \sin(\pi/2 - \alpha)$ . From the relation in (1), then, we find the cyclotron frequency to be  $(eH/mc)(1 - v^2/c^2)^{1/2}$ . This derivation of the relation for the cyclotron frequency from the point of view of aberration is exact.

Insight into the relativistic velocity of an electron can be provided by considering the mechanism by which the velocity of an electron is determined. An electrostatic spectrograph to determine the velocity of an electron consists in balancing the magnetic and electric deflections against each other [9]. The electron moving in a uniform magnetic field  $\mathbf{H}$ , perpendicularly to  $\mathbf{H}$ , describes a circular path of radius  $R_H$ :  $mv^2/R_H = e\mathbf{v}/c \times \mathbf{H}$ . If this electron moves in a radial electric field  $\mathbf{E}$ , it can describe a circular path of radius  $R_E$  given by  $mv^2/R_E = e\mathbf{E}$ . The equation of motion for the electron moving in the fields  $\mathbf{H}$  and  $\mathbf{E}$  applied simultaneously is then given by balancing the centrifugal force arising from the magnetic deflection against the centrifugal force due to the electric deflection, by  $e\mathbf{E}R_E = e\mathbf{v}/c \times \mathbf{H}R_H$ . Taking into account the aberration occurring in the form of the vector difference between  $\mathbf{v}$  and  $\mathbf{H}$ , the angle between  $\mathbf{v}$  and  $\mathbf{H}$  is tilted at an angle of aberration toward the direction of motion of the moving electron. The equation of motion is therefore  $cER_E = vHR_H \sin(\pi/2 - \alpha)$ . Consequently, the apparent velocity of the electron is found to be  $cER_E/HR_H(1 - \beta^2)^{1/2}$ , where  $\beta = ER_E/HR_H$ . In this regard,  $cER_E/HR_H$ , generally recognized as the velocity of the electron, is seen to be the velocity the electron would have if the velocity of propagation of the fields were

infinite, thereby not suffering aberration. In fact, the speeds of high-energy particles are frequently superluminal phenomenologically. It should be emphasized that these particles' speeds are ascribed not to the phenomenon of time dilation but to the apparent velocity of the fields as affected by the motion of the particles. Again, the consideration leads us to the conclusion that, phenomenologically, a particle velocity itself would appear dilated to the observer, keeping its time intact. The aberration of uniform magnetic field furnishes physical support for that conclusion.

## 6 Covariant Maxwell Equations

We consider the electromagnetic fields seen by an observer in the system  $S$  when a point charge  $q$  moves by in a straightline path along the  $x$  direction with a velocity  $\mathbf{v}$ . Let  $S'$  be the moving coordinate system of  $q$ . The charge is at rest in this system. But when viewed from the laboratory, the charge represents a current  $\mathbf{J} = q\mathbf{v}$  in the  $x$  direction. The electromagnetic fields are then related through Ampère's law:

$$\left[ \nabla \times \mathbf{B} = \frac{4\pi}{c} \mathbf{J} + \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t} \right]_S = \left[ \nabla \times \mathbf{B} = \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t} \right]_{S'}. \quad (14)$$

The  $y$  and  $z$  components of this equation are homogeneous equations. Let us apply to these homogeneous equations the Lorentz transformation of coordinates with  $[\gamma(ct - \beta x), \gamma(x - vt), y, z]_S = [ct, x, y, z]_{S'}$ . We obtain in the system  $S$  the equations

$$\frac{\partial B_x}{\partial z'} - \frac{\partial}{\partial x'} \left\{ \gamma \left( B_z - \frac{v}{c} E_y \right) \right\} = \frac{1}{c} \frac{\partial}{\partial t'} \left\{ \gamma \left( E_y - \frac{v}{c} B_z \right) \right\}, \quad (15)$$

$$\frac{\partial}{\partial x'} \left\{ \gamma \left( B_y + \frac{v}{c} E_z \right) \right\} - \frac{\partial B_x}{\partial y'} = \frac{1}{c} \frac{\partial}{\partial t'} \left\{ \gamma \left( E_z + \frac{v}{c} B_y \right) \right\}. \quad (16)$$

The covariance of these components of equation under the Lorentz transformation was explicitly shown by Lorentz [10] and Einstein [11]. But it would seem that its  $x$  component was assumed there implicitly. The transformation of the  $x$  component can also be shown explicitly.

We may write the  $x$  component of this equation, using Coulomb's law  $\nabla \cdot \mathbf{E} = 4\pi q$ , as

$$\frac{\partial B_z}{\partial y} - \frac{\partial B_y}{\partial z} = \frac{v}{c} (\nabla \cdot \mathbf{E}) + \frac{1}{c} \frac{\partial E_x}{\partial t}. \quad (17)$$

By multiplying this equation with  $\gamma$ , we are led to

$$\frac{\partial}{\partial y'} \left\{ \gamma \left( B_z - \frac{v}{c} E_y \right) \right\} - \frac{\partial}{\partial z'} \left\{ \gamma \left( B_y + \frac{v}{c} E_z \right) \right\} = \frac{1}{c} \frac{\partial E_x}{\partial t'} \quad (18)$$

when we use the inverse Lorentz transformation of coordinates. The inverse equations differ from the Lorentz transformation equations only by a change in the sign of  $\mathbf{v}$ , and  $\gamma$ -factor is symmetric with respect to the two systems in relative motion.

We may start with Faraday's law. In exactly the same manner, then, we use the relation,  $\nabla \cdot \mathbf{B} = 0$ , to obtain the equations of transformation. This completes the

demonstration of the transformation of electromagnetic fields. Consequently, the explicit equations of transformation are

$$\begin{aligned} E_{x'} &= E_x, & B_{x'} &= B_x, \\ E_{y'} &= \gamma(E_y - \beta B_z), & B_{y'} &= \gamma(B_y + \beta E_z), \\ E_{z'} &= \gamma(E_z + \beta B_y), & B_{z'} &= \gamma(B_z - \beta E_y). \end{aligned} \tag{19}$$

It is instructive to note that the transformation equations are obtained in an explicitly covariant form directly from the Maxwell equations themselves without using the mathematical property of the field-strength tensor of rank two.

## 7 Conclusion

The discussion in this paper shows that the origin of special relativity physics lies in the aberration effect. This discussion is based on the Galilean concepts of time and simultaneity, in which the velocity of light would appear dilated to the observer. It has shown that the alternative point of view constructs a new way of deriving familiar results. Obviously it leads us to an understanding of relativistic phenomena using a unified concept. This is in contrast with the current explanation that has given rise to much controversy. In controversy, the incorrect argument is in Einstein's theory, which is founded upon the mathematical concepts of time and simultaneity, not in opponents' minds pointing them out. The current concepts are the result of confusion leading us to a misunderstanding of relativistic phenomena.

We are taught special relativity in such a way that the equations of motion must be covariant in the mathematical structure of space and time. By identical treatment of space and time, as Minkowski addressed, the forms in which the equations of motion are displayed gain in intelligibility [12]. All of us would agree up to this point. But when applied identically to two systems in a relative motion, we are divided roughly into two groups, believers and skeptics. Believers are confident of Einstein's theory from its correct results. Sketics point out its inconsistent argument before experimental evaluation. This paper has been an attempt to find its phenomenological explanation from sketics' point of view. The correct result does not always warrant the correctness of assumption. As noted by Sommerfeld, the fourth coordinate is not  $t$  but  $ct$  [13]. In case of two systems in relative motion, furthermore, it must be the velocity of light that would appear dilated to each other.

## References

- [1] F. T. Jenkins and H. E. White, *Fundamentals of Optics* (McGraw-Hill, New York, 1976) 4th ed., p. 416.
- [2] J. W. S. Rayleigh, *The Theory of Sound* (Dover, New York, 1945) vol. 2, p. 155.
- [3] M. Jakobson, A. Shulz, and J. Steinberger, *Phys. Rev.* **81** (1951) 894; C. E. Wiegand, *Phys. Rev.* **83** (1951) 1085.
- [4] R. P. Durbin, H. H. Loar, and W. W. Havens Jr, *Phys. Rev.* **88** (1952) 179.

- [5] Review report, “Quasar’s Jet; Faster Than Light?” *Science in Korea* (1982) 24.
- [6] W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism* (Addison-Wesley, Reading, 1962) 2nd ed., p. 303.
- [7] H. Goldstein, *Classical Mechanics* (Addison-Wesley, Reading, 1950), p. 202.
- [8] C. G. Adler, *Am. J. Phys.* **55** (1987) 739; L. B. Okun, *Physics Today* (June 1989) 31.
- [9] M. M. Rogers, A. W. McReynolds, and F. T. Rogers Jr, *Phys. Rev.* **57** (1940) 379.
- [10] H. A. Lorentz, A. Einstein, H. Minkowski, and H. Weyl, *The Principle of Relativity* (Dover, New York, 1952), p. 14.
- [11] Reference 10, p. 52.
- [12] Reference 10, p. 75.
- [13] Reference 10, p. 92.

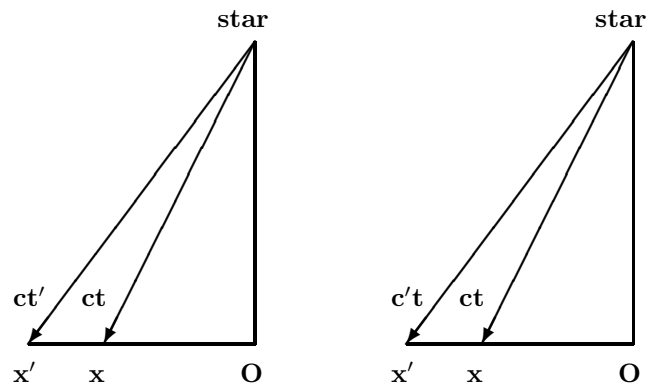


Figure 1: Illustration of the Lorentz condition and the Bradley relation